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SÍNDROME DE EMBOLIA GRASA TRAS FRACTURA FEMORAL: RECONOCIMIENTO PRECOZ, CONFIRMACIÓN DIAGNÓSTICA Y ESTRATEGIA TERAPÉUTICA

FAT EMBOLISM SYNDROME AFTER FEMORAL FRACTURE: EARLY RECOGNITION, DIAGNOSTIC CONFIRMATION, AND THERAPEUTIC STRATEGY

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Resumen

Introducción: El síndrome de embolia grasa (SEG) es una complicación infrecuente pero potencialmente mortal de las fracturas femorales y de otros huesos largos. No existe una prueba diagnóstica patrón oro validada y la tríada clásica de hipoxemia, deterioro neurológico y petequias suele ser incompleta. Métodos: Se realizó una actualización multidominio de la evidencia hasta el 30 de agosto de 2026. La base epidemiológica histórica se apoyó en una revisión sistemática previa de fracturas femorales (1960–2019) y se complementó mediante búsquedas en PubMed/MEDLINE, PubMed Central y rastreo de referencias para identificar cohortes contemporáneas, estudios diagnósticos, ensayos aleatorizados y síntesis de alta relevancia. La heterogeneidad impidió un nuevo metaanálisis. Resultados: La revisión histórica incluyó 15 estudios (n=3.095) y mostró una reducción de la incidencia clínica desde 7,9% en 1960–1979 hasta 1,7% en 2000–2019. Cohortes administrativas contemporáneas informan incidencias codificadas de 0,03–0,04%, mientras que una cohorte de centro de trauma de 2026 informó 4,3%. La fractura femoral, las fracturas múltiples, la edad joven y el trauma de alta energía aumentan el riesgo. La hipoxemia de nueva aparición y el deterioro neurológico durante las primeras 12–72 h constituyen las señales más útiles. La RM cerebral con DWI y SWI aporta el mayor apoyo radiológico en el SEG cerebral. El tratamiento se basa en soporte orgánico y estabilización oportuna de la fractura. Los corticoides profilácticos muestran una señal de beneficio en ensayos antiguos, pero sin evidencia robusta de reducción de mortalidad. Conclusiones: El SEG debe considerarse un diagnóstico clinicorradiológico de exclusión y de reconocimiento urgente. La vigilancia durante las primeras 72 h, la investigación temprana de hipoxemia o deterioro neurológico, el uso selectivo de RM y el soporte crítico moderno constituyen la estrategia más sólida. No existe evidencia suficiente para recomendar anticoagulación específica o corticoides de rutina para el SEG establecido.

Palabras claves: síndrome de embolia grasa; fractura de fémur; fractura de huesos largos; hipoxemia; embolia grasa cerebral; resonancia magnética; fijación de fracturas; trauma.

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Abstract

Background: Fat embolism syndrome (FES) is an uncommon but potentially life-threatening complication of femoral and other long-bone fractures. Its diagnosis remains difficult because no validated gold-standard test exists, and the classic triad of hypoxemia, neurologic dysfunction, and petechiae is often incomplete. This updated systematic review summarizes evidence relevant to early recognition, diagnostic confirmation, prevention, and treatment. Methods: A multidomain evidence update was performed through 30 August 2026. The historical epidemiologic evidence base was anchored to a prior systematic review of femoral fractures (1960–2019), and PubMed/MEDLINE, PubMed Central, and backward citation searches were used to identify contemporary cohort, diagnostic, randomized, and high-value synthesis studies. Evidence was synthesized qualitatively because diagnostic definitions, populations, and interventions were heterogeneous. Results: The historical review included 15 studies (n=3,095) and documented a fall in clinically diagnosed FES from 7.9% in 1960–1979 to 1.7% in 2000–2019. Contemporary administrative cohorts report much lower coded incidence (approximately 0.03–0.04%), whereas a 2026 trauma-center cohort reported 4.3%, highlighting persistent case-definition effects. Femoral fracture, multiple long-bone fractures, younger age, and high-energy trauma consistently increase risk. New hypoxemia and neurologic deterioration within 12–72 h are the most useful early signals; petechiae are specific when present but insensitive. Gurd–Wilson and Schonfeld criteria remain supportive rather than confirmatory. Chest CT can demonstrate bilateral ground-glass or centrilobular opacities but is nonspecific; brain MRI with diffusion-weighted imaging and susceptibility-weighted imaging provides the strongest imaging support for cerebral FES. Bronchoalveolar lavage fat-laden macrophages lack adequate specificity. The therapeutic cornerstone is organ support and timely fracture stabilization when physiologically appropriate. Older randomized trials suggest that prophylactic corticosteroids reduce FES and hypoxemia, but the evidence is small, dated, and methodologically limited, with no proven mortality benefit. Conclusions: FES should be treated as a time-sensitive clinicoradiologic diagnosis of exclusion. A structured first-72-hour surveillance strategy, early investigation of unexplained hypoxemia or neurologic change, selective MRI confirmation, and modern supportive critical care offer the most defensible approach. Routine disease-specific anticoagulation or corticosteroid therapy for established FES cannot be recommended from current evidence.

Keywords: fat embolism syndrome; femoral fracture; long-bone fracture; hypoxemia; cerebral fat embolism; magnetic resonance imaging; fracture fixation; trauma.

1. Introduction

Fat embolization is frequent after major skeletal trauma, but the clinical fat embolism syndrome (FES) is much less common. The distinction is clinically important: circulating marrow fat or intraoperative embolic showers can occur without organ dysfunction, whereas FES denotes a systemic inflammatory and microvascular syndrome dominated by respiratory and neurologic injury. Femoral fractures are the prototypic setting because of the large intramedullary fat reservoir and the high-energy mechanisms that often accompany shaft fractures and polytrauma. [1–4]

FES remains diagnostically difficult more than five decades after the original criteria proposed by Gurd and later modified with Wilson. [1,2] No biomarker, imaging sign, or clinical score has adequate sensitivity and specificity to function as a stand-alone reference standard.

Consequently, published incidence varies widely according to population, diagnostic definition, timing of surveillance, and whether cases are identified prospectively, clinically, radiologically, administratively, or at autopsy. A systematic review of femoral-fracture studies demonstrated a marked temporal decline in incidence, but contemporary datasets continue to produce estimates ranging from hundredths of a percent to several percent. [3–7]

The practical problem is therefore not simply whether FES exists, but how to recognize it before severe hypoxemic respiratory failure or cerebral involvement becomes established, how to use imaging without overdiagnosing nonspecific trauma-related changes, and which therapeutic measures are supported by evidence. The objective of this updated systematic review and evidence synthesis was to integrate the epidemiologic, diagnostic, preventive, and therapeutic literature relevant to FES after femoral fracture and to translate it into a clinically usable pathway.

2. Methods

2.1 Review design and reporting

This manuscript was designed as an updated systematic review with narrative clinical synthesis. PRISMA 2020 principles were applied where compatible with an evidence update spanning several domains (epidemiology/risk, diagnostic confirmation, prevention, and treatment). Because the included literature uses nonuniform definitions of FES and markedly different study designs, no new pooled meta-analysis was performed. The protocol was not prospectively registered; this is acknowledged as a limitation and should be considered when interpreting the review.

2.2 Evidence sources and search strategy

The historical epidemiologic and fracture-management evidence base was anchored to the systematic review by Lempert et al., which searched MEDLINE, Embase, PubMed, and the Cochrane Central Register of Controlled Trials for studies published from 1960 through 31 December 2019 and screened 1,024 records, of which 15 studies

(n=3,095) were included. [3] An update was then undertaken through 30 August 2026 using PubMed/MEDLINE, PubMed Central, targeted journal searches, and backward citation searching. Search concepts combined “fat embolism syndrome,” “fat embolism,” “femur,” “femoral fracture,” “long-bone fracture,” “early fixation,” “intramedullary nailing,” “diagnosis,” “Gurd,” “Schonfeld,” “magnetic resonance imaging,” “diffusion-weighted imaging,” “susceptibility-weighted imaging,” “computed tomography,” “bronchoalveolar lavage,” “corticosteroid,” “methylprednisolone,” “ARDS,” and “ECMO.”

For contemporary epidemiology, priority was given to large trauma datasets and cohorts published after the end date of the historical systematic review. For diagnosis and treatment, primary diagnostic studies, randomized or comparative intervention studies, and systematic reviews/meta-analyses were used to identify the most reproducible findings and to avoid over-weighting isolated case reports. Recent case series were used only when they provided clinically relevant information not available from higher-level evidence.

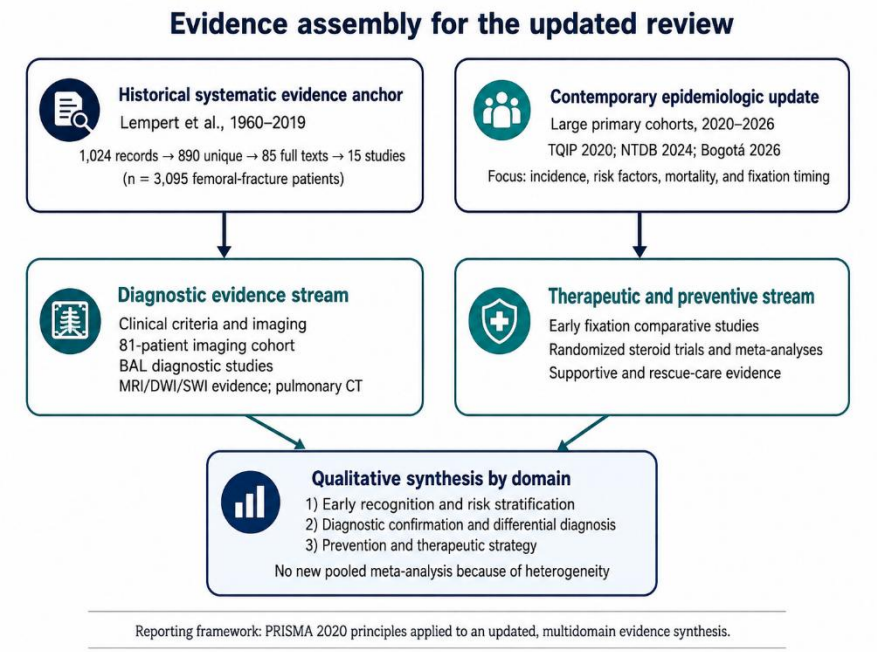
2.3 Eligibility criteria

Eligible evidence involved adolescents or adults with traumatic femoral or other major long-bone fractures and reported at least one of the following: incidence or risk factors for FES; timing or clinical presentation; performance or clinical utility of diagnostic criteria, laboratory findings, chest imaging, neuroimaging, or bronchoalveolar lavage; fracture stabilization as a preventive strategy; pharmacologic prophylaxis or treatment; critical-care support; or outcomes. Randomized trials, prospective and retrospective cohorts, case-control studies, diagnostic cohorts, case series with at least five patients, and high-quality systematic reviews/meta-analyses were considered. Isolated case reports, nontraumatic FES, elective arthroplasty-only studies, animal studies, and publications without usable clinical outcomes were excluded from the principal synthesis, although exceptional rescue-therapy reports were discussed as very-low-certainty evidence.

2.4 Data extraction and synthesis

Data were extracted into domain-specific evidence tables capturing study design, population, fracture pattern, FES definition, timing, diagnostic findings, intervention, and outcomes. Eligibility and numerical results were cross-checked against PubMed records or accessible full text when available. Given the absence of a validated reference standard, incidence estimates were not pooled across studies with different case definitions. Diagnostic evidence was interpreted as supportive rather than as formal diagnostic-accuracy meta-analysis. Certainty was graded qualitatively as moderate, low, or very low according to study design, consistency, directness, precision, and risk of misclassification.

Figure 1. *Evidence-base assembly for this updated systematic review and clinical synthesis.*



3. Results

3.1 Incidence, temporal trends, and high-risk phenotypes

The strongest consistent finding is that reported FES incidence is highly dependent on how the syndrome is defined. In the 15-study femoral-fracture systematic review (n=3,095), incidence fell from 7.9% in studies from 1960–1979 to 4.8% in 1980–1999 and 1.7% in 2000–2019. [3] In a US National Hospital Discharge Survey analysis, FES was recorded in 0.12% of patients with isolated at-risk fractures overall, but occurred

more often with multiple femoral fractures than isolated femoral fractures. [4] A 2020 Trauma Quality Improvement Program analysis of 324,165 patients with extremity fractures identified only 116 coded FES cases (0.04%), whereas a 2024 National Trauma Data Bank study identified 344 FES cases among 1,251,143 patients (0.03%). [5,6] These administrative estimates are likely specific but may be insensitive because the diagnosis depends on coding and documentation.

A large contemporary single-center trauma cohort from Bogotá provides a contrasting estimate: among 3,475 adults with long-bone fractures, FES occurred in 4.3% (n=148) with 5.4% in-hospital mortality. Femoral fracture was the strongest independent risk factor (adjusted OR 4.63, 95% CI 2.99–7.22), and early fixation within 24 h was protective (adjusted OR 0.42, 95% CI 0.25–0.71). [7] This difference from administrative datasets illustrates why incidence should not be quoted as one universal number.

Across studies, risk clusters around younger age, femoral fracture, bilateral or multiple long-bone fractures, high-energy trauma, major displacement, and polytrauma. [3,5–9] The 2017 Brazilian femoral-shaft cohort documented six FES cases among 272 patients and found polytrauma, rather than the provisional fixation method itself, to be the main correlate. [9] Historical trauma-center experience similarly associated clinically overt FES with greater injury burden. [8]

3.2 Timing and early clinical recognition

The classic syndrome usually appears after an initially stable interval, most often within 12–72 h after injury or orthopedic manipulation. A fulminant form can occur earlier and is characterized by abrupt respiratory and right-heart failure, but the more common pattern is progressive hypoxemia followed by neurologic dysfunction, fever, tachycardia, thrombocytopenia or anemia, and occasionally petechiae. [10–13] Clinicians should therefore not wait for the complete triad before escalating evaluation.

In the 81-patient imaging-correlated cohort by Shaikh et al., respiratory insufficiency was present in 98%, neurologic deterioration in 70%, but petechial rash in only 2.5%. [13] This

reinforces two practical points: hypoxemia is the most sensitive bedside warning signal, and the absence of petechiae does not meaningfully exclude FES. Recent small case series have similarly emphasized early oxygen desaturation, falling hemoglobin and platelet counts, and inflammatory-marker rises, but biomarker thresholds are not sufficiently validated for diagnostic use. [30]

Table 1. *Common diagnostic frameworks and their limitations.*

Framework	Diagnostic components	Typical threshold	Main limitation
Gurd–Wilson	Major: respiratory insufficiency with radiographic change; cerebral signs unrelated to head injury; petechial rash. Minor findings include tachycardia, fever, retinal/renal changes, anemia, thrombocytopenia and others.	Historically 2 major, or 1 major + 4 minor (variants exist).	No prospective validation; several items are subjective or nonspecific; performance depends on how criteria are operationalized.
Schonfeld score	Petechiae (5), diffuse chest infiltrates (4), hypoxemia (3), fever (1), tachycardia (1), tachypnea (1), confusion (1).	Score >5 commonly used.	Semiquantitative but not validated against an accepted reference standard.
Lindeque	Physiologic respiratory criteria based on PaO_2, $PaCO_2$/pH, respiratory rate and respiratory distress.	At least one respiratory criterion in the original proposal.	May increase sensitivity but over-calls nonspecific post-traumatic respiratory failure; ignores multisystem pattern.
Clinicoradiologic approach	Compatible trauma setting + unexplained respiratory/neurologic deterioration + supportive imaging, after exclusion of major mimics.	No single numeric threshold.	Most clinically realistic approach, but still lacks a gold-standard confirmatory test.

3.3 Diagnostic confirmation: what adds value?

3.3.1 Laboratory testing

Routine laboratory abnormalities—falling hemoglobin, thrombocytopenia, elevated inflammatory markers, hypoxemia on arterial blood gas, and occasionally coagulopathy—are common but nonspecific. Fat globules in blood, urine, or sputum indicate fat embolization but do not prove the clinical syndrome. No circulating lipid, lipase, inflammatory cytokine, or other biomarker has reached sufficient validation to serve as a confirmatory test. Laboratory testing is therefore best used to detect physiologic deterioration and competing diagnoses rather than to “rule in” FES.

3.3.2 Chest radiography and CT

Chest radiographs may show bilateral diffuse or patchy infiltrates, but these findings overlap with pulmonary contusion, aspiration, edema, pneumonia, transfusion-associated lung injury, and ARDS from other causes. Chest CT more often demonstrates bilateral ground-glass opacities, ill-defined centrilobular nodules, interlobular septal thickening, or patchy consolidation. [14,28] In the Shaikh cohort, CT demonstrated patchy alveolar opacities in 60.5% of patients. [13] CT pulmonary angiography is useful when thrombotic pulmonary embolism must be excluded, but a normal pulmonary angiogram does not exclude FES because the pathologic process is predominantly microvascular and inflammatory.

3.3.3 Brain CT and MRI

Neurologic FES is the setting in which imaging is most likely to alter diagnostic confidence. Head CT may be normal or show nonspecific cerebral edema. By contrast, brain MRI can demonstrate a characteristic “starfield” pattern of multiple punctate foci of restricted diffusion, particularly in the acute phase. [15,16] A systematic review of cerebral FES imaging described five evolving MRI patterns: scattered embolic ischemia, confluent symmetric cytotoxic white-matter edema, vasogenic edema, petechial hemorrhage, and chronic sequelae. [15] Susceptibility-weighted imaging can reveal numerous microhemorrhagic foci that may be more conspicuous than lesions on conventional sequences. Accordingly, DWI and SWI should be included when unexplained neurologic deterioration persists after femoral or multiple long-bone trauma.

3.3.4 Bronchoalveolar lavage and other invasive tests

Bronchoalveolar lavage (BAL) has repeatedly failed to provide adequate specificity. Stanley et al. found lipid-laden macrophages above a proposed threshold in most non-FES pulmonary patients, yielding a specificity of only 26.5%. [17] Roger et al. similarly found Oil Red O-positive macrophages in trauma patients both with and without clinical FES. [18] BAL may document pulmonary fat exposure but should not be used routinely to confirm FES.

Transesophageal echocardiography and transcranial Doppler can demonstrate embolic showers during orthopedic procedures, yet these techniques identify embolization rather than the syndrome and are not standard diagnostic tests for postoperative deterioration.

Table 2. *Representative evidence informing recognition, diagnosis, and risk stratification.*

Study	Design / sample	Key finding	Interpretation
Lempert et al., 2021 [3]	Systematic review; 15 studies; n=3,095 femoral-fracture patients	FES incidence declined from 7.9% (1960–1979) to 1.7% (2000–2019); bilateral/pathologic injury patterns had higher rates than unilateral high-energy fractures.	Best historical synthesis; substantial heterogeneity in diagnostic definitions.
Alpert et al., 2020 [5]	TQIP cohort; n=324,165 extremity-fracture patients	116 coded FES cases (0.04%); age ≤30, closed femur fracture, and multiple long-bone fractures associated with FES.	Large contemporary dataset; likely under-detection from administrative coding.
Owattanapanich et al., 2024 [6]	NTDB study; n=1,251,143; 344 FES cases	FES associated with higher mortality (7% vs 1% in matched comparison).	Supports clinical relevance despite very low coded incidence.
Gavidia Bernal et al., 2026 [7]	Retrospective trauma cohort; n=3,475	FES 4.3%; femoral fracture aOR 4.63; early fixation <24 h aOR 0.42; in-hospital mortality 5.4%.	Contemporary clinically detected cohort; demonstrates case-definition effect and protective association of early fixation.
Shaikh et al., 2018 [13]	Clinical/imaging cohort; n=81 FES patients	Respiratory insufficiency 98%, neurologic decline 70%, petechiae 2.5%; CT chest opacities 60.5%; MRI starfield 28.4%.	Useful description of real-world presentation; lacks independent gold standard.
Stanley et al., 1994 [17]	BAL specificity study; n=34 non-FES pulmonary patients	>5% lipid-laden BAL cells in 25/34; specificity only 26.5%.	Strong argument against BAL as a stand-alone diagnostic test.
Roger et al., 1995 [18]	BAL study; trauma + nontrauma controls	Oil Red O-positive macrophages occurred in trauma patients with and without FES.	Fat-laden macrophages reflect embolization/exposure, not necessarily clinical FES.

3.4 Prevention and timing of fracture stabilization

The most consistent modifiable strategy is timely stabilization of the fracture, provided the patient's physiology permits definitive surgery. In Svenningsen et al., delayed fixation after 4–7 days was associated with FES in 10.4% of patients compared with 1.8% after immediate osteosynthesis. [10] Pinney et al. reported FES in 11 of 274 isolated femoral-shaft fractures (4% overall); among patients younger than 35 years, no cases occurred in 60 patients nailed within 10 h, whereas 11 of 109 nailed after 10 h developed FES. [11] Contemporary cohort data also support an association between fixation within 24 h and reduced FES risk. [7]

These data should not be interpreted as a mandate for immediate definitive intramedullary nailing in every unstable polytrauma patient. The modern principle is early appropriate care: minimize unnecessary fracture motion, resuscitate promptly, and choose definitive fixation versus damage-control orthopedics according to hemodynamic, respiratory, metabolic, and associated-injury status. Reviews of major long-bone fracture management emphasize that FES is multifactorial and cannot be completely prevented by timing alone. [12,32]

3.5 Pharmacologic prophylaxis and treatment

3.5.1 Corticosteroids

Corticosteroids have the largest historical pharmacologic evidence base, but most trials predate contemporary trauma systems and modern fixation techniques. In the randomized double-blind Schonfeld trial, FES occurred in 0 of 21 corticosteroid-treated patients versus 9 of 41 placebo patients. [20] Other trials by Alho, Stoltenberg, Lindeque, and Babalis generally reported less hypoxemia or fewer FES events with methylprednisolone, although doses, definitions, and trial quality varied substantially. [21–24] In the 2004 Babalis trial, FES occurred in 2.5% of the steroid group and 12.8% of controls, but the difference did not reach conventional statistical significance (P=0.079). [24]

A meta-analysis of seven randomized trials (389 patients) estimated a 78% relative reduction in FES with corticosteroid prophylaxis and a number needed to treat of 8, while finding no significant mortality or infection benefit. Importantly, the authors rated the underlying trials as methodologically weak and did not recommend a routine practice change. [25] A separate meta-analysis reached a similar conclusion for FES and hypoxemia reduction. [26] These data support biologic plausibility and a preventive signal, but not a contemporary standard of care. Evidence for corticosteroids after FES is already established is even weaker and is dominated by uncontrolled reports; therefore, routine therapeutic steroids cannot be recommended solely for FES.

3.5.2 Anticoagulation, albumin, and other agents

Heparin has been proposed because it activates lipoprotein lipase, but there is no convincing clinical evidence that disease-specific anticoagulation improves FES, and trauma-related bleeding risk is substantial. Anticoagulation should therefore be prescribed for standard indications such as venous-thromboembolism prophylaxis or proven thrombotic embolism, not as treatment for fat microembolization itself. Albumin may be reasonable when clinically indicated for volume resuscitation because of free-fatty-acid binding, but no high-quality trial supports albumin as a disease-specific therapy. Dextrose, ethanol, dextran-based regimens, and other historical approaches have not become standard practice.

3.5.3 Respiratory, neurologic, and hemodynamic support

Supportive critical care remains the therapeutic cornerstone. Supplemental oxygen and close monitoring may be sufficient in mild disease. Patients with ARDS should receive lung-protective ventilation and standard evidence-based ARDS care. Hemodynamic support should target adequate perfusion while avoiding unnecessary fluid overload; vasopressors and inotropes are used when shock or right-ventricular failure develops. Fever, seizures, agitation, and secondary brain injury should be treated conventionally. [27,32]

For refractory hypoxemia or circulatory collapse, extracorporeal membrane oxygenation (ECMO) has been used successfully in highly selected cases. Published evidence remains limited to case reports and small series, including recent VV-ECMO and VA-ECMO rescue experiences. [31] ECMO should therefore be viewed as a rescue option in expert centers rather than a standard FES therapy, particularly because anticoagulation and bleeding risk are major concerns in polytrauma.

Table 3. *Therapeutic strategy and certainty of evidence.*

Intervention	Evidence signal	Certainty	Practical recommendation
Early fracture stabilization when physiologically appropriate	Historical comparative studies and contemporary cohort associations consistently favor earlier stabilization.	Moderate	Recommended as part of modern trauma care; use damage-control orthopedics if definitive fixation is unsafe.

Intervention	Evidence signal	Certainty	Practical recommendation
Oxygen / lung-protective ventilation / standard ARDS care	Universal supportive-care principle; direct randomized FES trials are not feasible.	Moderate (indirect)	Standard of care.
Corticosteroid prophylaxis	Older randomized trials and meta-analyses show fewer FES/hypoxemia events but no proven mortality benefit; trials are small and dated.	Low	Do not use routinely; may be a research or protocolized-center decision.
Corticosteroids for established FES	Mostly uncontrolled reports; no robust randomized therapeutic evidence.	Very low	Not recommended routinely solely for FES.
Therapeutic heparin for FES	No convincing clinical benefit; meaningful bleeding risk in trauma.	Very low	Do not use for FES alone. Use anticoagulation only for standard indications.
Albumin as disease-specific therapy	Physiologic rationale but no high-quality clinical evidence.	Very low	Use only when otherwise indicated for resuscitation, not as specific FES treatment.
ECMO	Case reports/small series in refractory ARDS or shock.	Very low	Rescue therapy in selected patients at experienced centers.

3.6 Quality and limitations of the evidence

The overall certainty of evidence is limited by three recurring problems. First, there is no accepted diagnostic reference standard, so both underdiagnosis and overdiagnosis are plausible. Second, administrative datasets achieve enormous sample size at the cost of dependence on coding, whereas clinically adjudicated series are richer but smaller and more vulnerable to referral bias. Third, most randomized corticosteroid trials are several decades old, used heterogeneous doses and diagnostic definitions, and preceded current trauma resuscitation, ventilatory care, and fixation strategies. These limitations explain why incidence estimates vary by orders of magnitude and why no disease-specific drug has achieved broad guideline-level acceptance.

4. Discussion

This synthesis supports a practical reframing of FES. The syndrome should not be approached as a diagnosis that requires the classic triad or a single positive test. Instead, clinicians should recognize a high-risk context—especially femoral, bilateral, or multiple long-bone fractures—and then identify a dynamic change in oxygenation, neurologic status, or systemic physiology during the first 72 h. A complete petechial eruption is diagnostically helpful when present,

but it is too insensitive to be used as a gatekeeper. [13]

The large discrepancy between modern administrative incidence estimates and clinically adjudicated trauma-center cohorts is not merely a statistical nuisance; it reflects the underlying diagnostic problem. [5–7] A coded incidence of 0.03% should not reassure clinicians that FES is almost nonexistent, just as older series reporting rates above 10% should not be applied uncritically to contemporary practice. The most defensible interpretation is that clinically significant FES is uncommon, but risk is concentrated in identifiable trauma phenotypes and the syndrome remains consequential when it occurs.

Diagnostic criteria remain useful as structured memory aids, not as validated confirmatory tools. Gurd–Wilson criteria capture the multisystem concept but include subjective and nonspecific components. Schonfeld provides a semiquantitative score, yet has not been prospectively validated against a true reference standard. Lindeque increases objectivity by emphasizing respiratory physiology but can classify nonspecific post-traumatic hypoxemia as FES. Accordingly, the diagnosis is best made through temporal pattern recognition plus exclusion of more common causes of deterioration.

Imaging should be used strategically. In a hypoxemic patient, chest CT can support the diagnosis while CT pulmonary angiography helps evaluate thrombotic embolism, but parenchymal opacities are not pathognomonic. Neuroimaging is more discriminating. In patients with new confusion, seizures, decreased consciousness, or focal neurologic abnormalities unexplained by head trauma or metabolic causes, MRI with DWI and SWI materially increases diagnostic confidence. [15,16] The starfield pattern is not present in every patient and evolves with time, so a normal early sequence does not entirely exclude cerebral FES; however, when typical lesions occur in the correct clinical context, they provide the strongest available confirmatory support.

Prevention and treatment should remain centered on trauma fundamentals. Gentle handling and prompt stabilization reduce ongoing marrow disruption, while the timing and technique of fixation must be

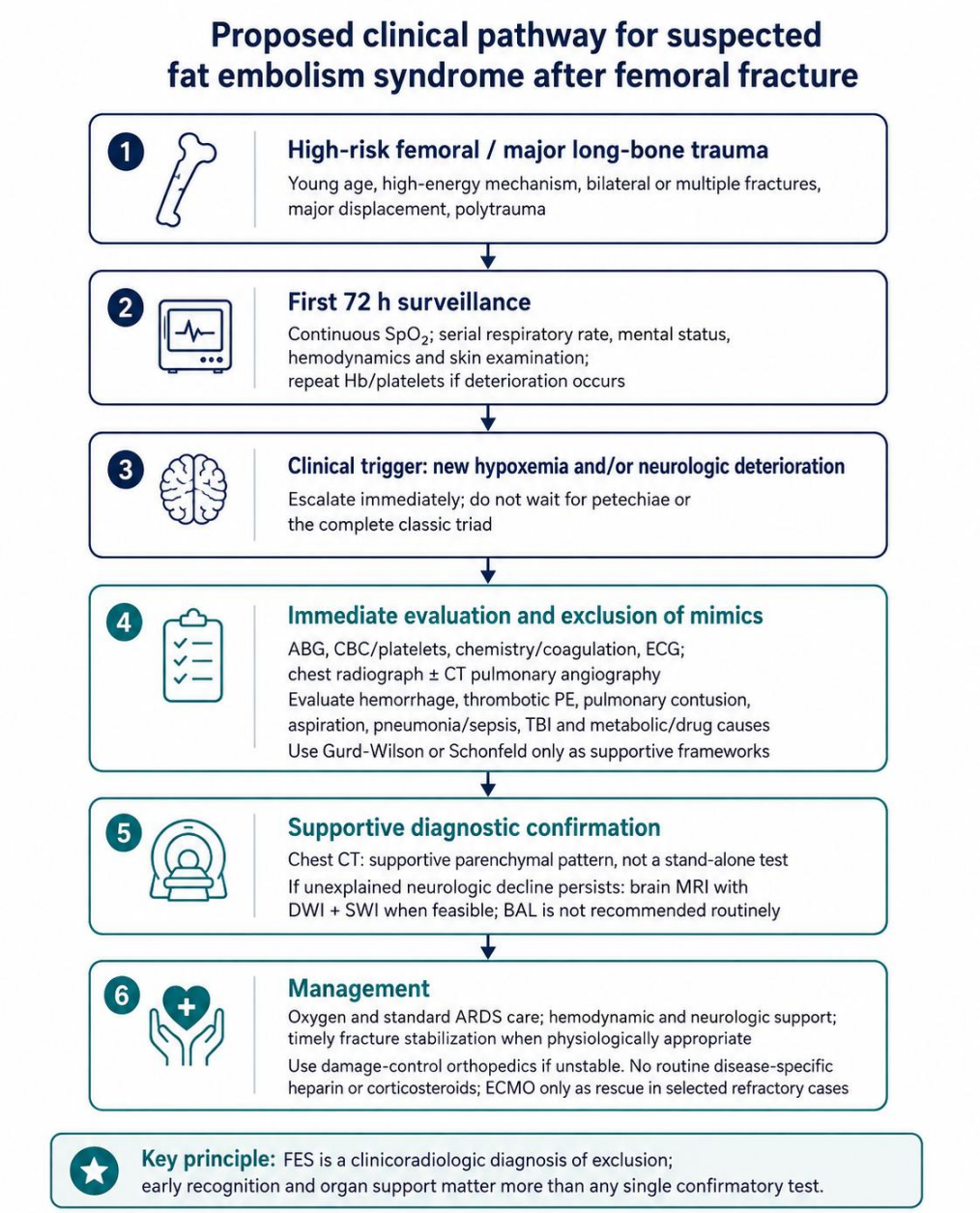
individualized to physiology. [7,10–12] The corticosteroid literature is a classic example of a statistically positive but clinically unsettled evidence base: pooled historical trials suggest fewer FES events, yet they are too small, heterogeneous, and dated to support routine prophylaxis in modern practice. [20–26] A well-designed contemporary multicenter trial would be required before this question can be considered resolved.

Once FES develops, high-quality organ support is more important than unproven disease-specific drugs. This includes oxygenation, lung-protective ventilation for ARDS, hemodynamic stabilization, and management of neurologic complications. Disease-specific heparin is not justified. Rescue ECMO may be lifesaving in exceptional refractory cases, but the evidence is necessarily very low certainty and the bleeding risk of extracorporeal support in trauma must be considered. [31]

4.1 Proposed first-72-hour surveillance strategy

A practical surveillance protocol after high-risk femoral fracture is: (1) continuous pulse oximetry during the early post-injury period; (2) serial respiratory rate, mental-status, skin, and hemodynamic assessment; (3) repeat hemoglobin and platelet counts when clinical status changes; (4) immediate arterial blood gas analysis and chest imaging for unexplained desaturation; (5) rapid exclusion of hemorrhage, pulmonary thromboembolism, aspiration, pulmonary contusion, sepsis, transfusion-related lung injury, and intracranial injury; and (6) MRI brain with DWI and SWI for persistent or unexplained neurologic deterioration. This approach is intentionally trigger-based rather than dependent on waiting for a full diagnostic score.

Figure 2. *Proposed clinical pathway for suspected FES after femoral fracture. The algorithm is an evidence-informed synthesis rather than a validated prediction rule.*



4.2 Strengths and limitations of this review

The main strength of this review is integration of historical femoral-fracture evidence with very large contemporary trauma datasets and focused diagnostic and therapeutic literature through August 2026. It also separates fat embolization from the clinical syndrome and avoids treating any single clinical score or imaging sign as a gold standard. Limitations include the use of an update strategy rather than a completely de novo search of every

subscription database, the lack of prospective protocol registration, substantial overlap among historical evidence syntheses, and the impossibility of formal diagnostic-accuracy pooling in the absence of a reference standard. Publication bias is especially relevant to cerebral FES and ECMO rescue reports. These limitations should be stated explicitly rather than hidden by an artificial pooled estimate.

5. Conclusiones

Fat embolism syndrome after femoral fracture remains uncommon but clinically important. The highest-risk phenotype includes younger patients with high-energy femoral, bilateral, or multiple long-bone fractures and substantial injury burden. New hypoxemia and neurologic deterioration during the first 12–72 h should trigger immediate evaluation even in the absence of petechiae. No diagnostic criterion or laboratory test is definitive. Chest CT is supportive and useful for differential diagnosis, while brain MRI with DWI and SWI offers the most specific imaging support for cerebral involvement. Bronchoalveolar lavage is not sufficiently specific for routine diagnostic use. Treatment should prioritize oxygenation, lung-protective ventilation when required, hemodynamic and neurologic support, and timely fracture stabilization according to the patient's physiologic state. Historical corticosteroid trials suggest prophylactic benefit but are insufficient to support routine modern use, and there is no evidence base for disease-specific heparin. ECMO is reserved for refractory respiratory or circulatory failure in selected patients. A structured first-72-hour surveillance pathway is the most immediately actionable strategy for reducing delayed recognition.

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